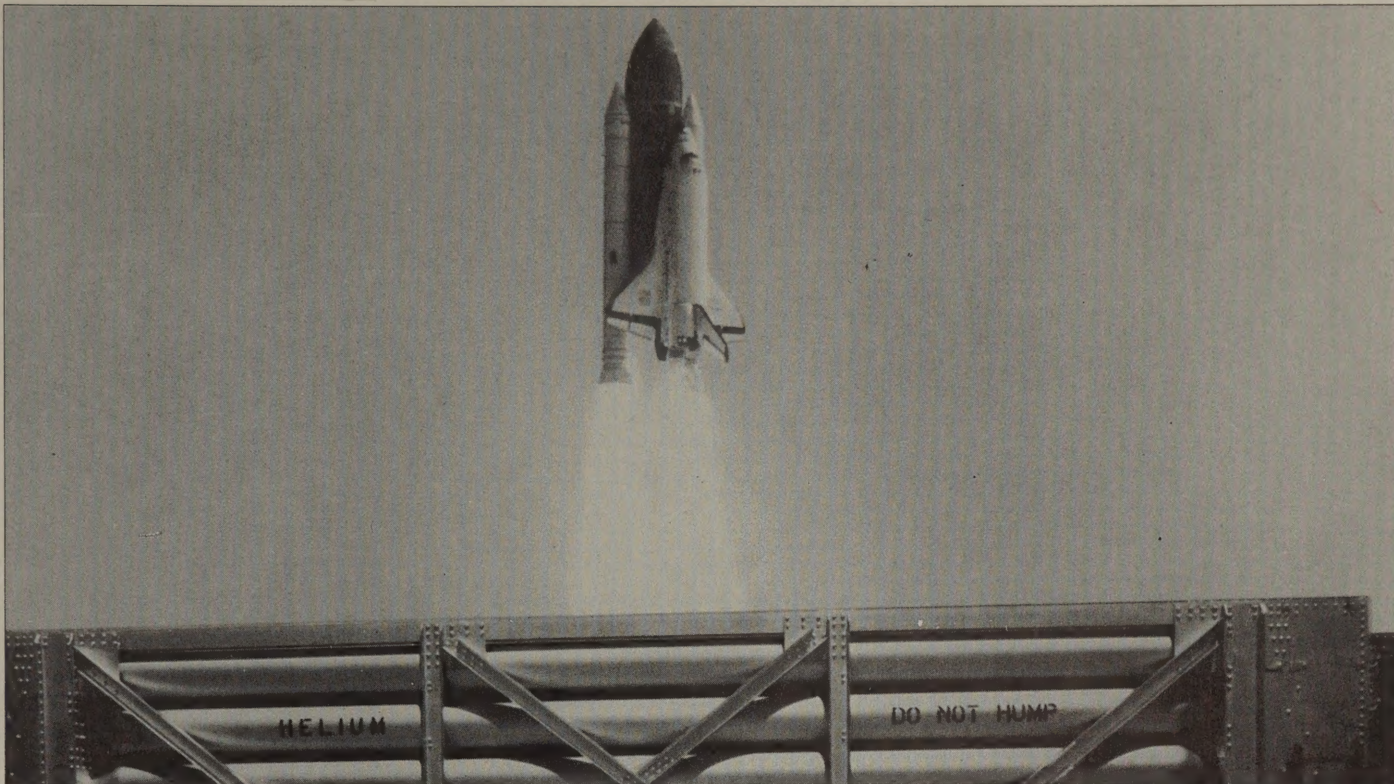
ANNUAL REPORT




# HELIUM

By William D. Leachman



1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

ANNUAL REPORT

# HELIUM

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

September 1991

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*COVER PHOTO:*
*The National Aeronautics and Space Administration (NASA) Kennedy Space Center (KSC) in Florida is the Bureau's largest single helium customer. Railroad tankcars owned by the Bureau supply large volumes of gaseous helium for purging the external tank and pressurizing liquid propellants used in the Space Shuttle's rocket engines. (Photo is courtesy of NASA, KSC.)*

# Tables



# Figures




*For comments or further information, please contact*
*Office of Planning and Analysis*
*Helium Field Operations*
*U.S. Bureau of Mines*
*1100 S. Fillmore St., MS 2310*
*Amarillo, TX 79101*
*Telephone: (806) 376-2604; FTS 735-1604*
*Fax: (806) 376-2633*

# HELIUM

By William D. Leachman

**Mr. Leachman, a chemical engineer with 37 years of industry and U.S. Bureau of Mines experience, has been the commodity specialist for helium since 1983. He also prepared the domestic survey data and the international data tables.**

Grade-A helium (99.995% or better) sales volume in the United States by private industry and the U.S. Bureau of Mines was 2,167 million cubic feet (MMcf) in 1990.[1] Grade-A helium exports by private producers were 892 MMcf, for total sales of 3,059 MMcf of U.S. helium. The price of Grade-A helium, f.o.b. plant, was about $37.50 per thousand cubic feet (Mcf) for both the Bureau and private industry. The Bureau price for bulk liquid helium was $45.00 per Mcf, with additional costs for container services and rent. The liquid helium price for private industry was also about $45.00 per Mcf, with some producers posting surcharges to this price.

## DOMESTIC DATA COVERAGE

Domestic production data for helium are developed by the U.S. Bureau of Mines from records of its own operations as well as the "High Purity Helium Survey," a single, voluntary canvass of private U.S. operations. Of the seven operations to which a survey request was sent, 100% responded, and those data plus data from the Bureau's operations represent 100% of the total helium sales and recovery shown in table 2.

## BACKGROUND

The U.S. Bureau of Mines role in helium matters dates back to the First World War when the Army and Navy became interested in using helium as an inert lifting gas and contacted the Bureau for assistance because of its natural gas expertise. In 1925, the Government's Helium Program was officially placed under Bureau control by Congress (Helium Act of 1925). In 1929, the Bureau's Amarillo, TX, large-scale helium extraction and purification facility was built and began operation. During World War II, demand increased significantly, and four more small Government helium plants were built.

New technology increased helium demand in the 1950's and led to the construction of the Keyes, OK, plant in 1959. Dwindling Hugoton-Panhandle Field natural gas supplies aroused concerns that no economic source of helium would exist by the turn of the century.

In 1960, Congress replaced the 1925 Act with new legislation. The purposes of the act were to provide for conservation of helium for essential Government activities and to promote development of a private helium industry. The act directed the Secretary of the Interior to purchase and store helium for future Government use and to operate and maintain helium production and purification plants and related helium storage, transmission, and shipping facilities.

Purchases for the conservation program were made under 22-year contracts with private natural gas companies, which added crude helium extraction capabilities to their existing gas processing facilities. Four companies built five crude helium plants. The Bureau constructed a high-pressure pipeline to transport the helium from Bushton, KS, and intermediate points to the Bureau-owned Cliffside Field for storage.

Helium needs of the Federal agencies, particularly the U.S. Department of Defense, the National Aeronautics and Space Administration (NASA), and the U.S. Department of Energy (DOE), have been met, and there is enough helium in storage to meet their foreseeable needs for up to 100 years, depending on how much helium will be needed by future Government programs. The entire Federal helium demand is now supplied by the Exell Helium Plant.

In the mid-1970's, the Bureau began accepting privately owned crude helium for storage in Cliffside under long-term contracts. Private industry currently has about a 6-month supply of helium in Government storage, assuming all private market requirements would come from storage.

### Geology-Resources

Domestic measured and indicated helium resources as of January 1, 1990, the latest figures available, are estimated to be 541 billion cubic feet (Bcf). The total identified helium resources are about 6 Bcf more than reported in 1989. The increase is attributed to the reevaluation of the helium reserves of several fields in Texas. The resources include measured reserves and indicated resources estimated at 256 and 32 Bcf, respectively, in natural gas with a minimum helium content of 0.3%. The measured reserves included 35 Bcf stored by the Bureau in the helium conservation storage system. Measured helium resources in natural gas with a helium content of less than 0.3% are estimated to be 40 Bcf. Indicated helium resources in natural gas with a helium content of less than 0.3% are estimated to be 213 Bcf. Approximately 165 Bcf or 92% of the domestic helium resources under Federal ownership are in the Riley Ridge area and the Church Buttes Field in Wyoming and in the Cliffside Field in Texas.

Most of the domestic helium resources are in the midcontinent and Rocky Mountain regions of the United States. The measured helium reserves are in approximately 95 gasfields in 11 States. About 83% of these reserves is

contained in the Hugoton Field in Kansas, Oklahoma, and Texas; the Keyes Field in Oklahoma; the Panhandle and Cliffside Fields in Texas; and the Riley Ridge area in Wyoming. The U.S. Bureau of Mines analyzed a total of 184 natural gas samples from 21 States during 1990 in conjunction with its program to survey and identify possible new sources of helium.

### Technology

Technology that uses liquid helium to produce superconducting temperatures continues to be developed and operated. Liquid helium continues to be used at Fermi National Accelerator Laboratory for Tevatron/Tevatron 1, which was the world's first superconducting particle accelerator. The liquid helium-cooled superconducting magnets used in this accelerator provide an intense and extremely steady magnetic field using only a fraction of the energy required by conventional electromagnets. The Tevatron is presently the highest-energy particle accelerator in the world (1.6 trillion electron volts). In addition, the DOE has already selected the magnets it proposes to use in the Superconducting Supercollider (SSC). The SSC magnets will be similar to those used at Fermi, which are liquid helium-cooled, because they have been proved and tested in operation. When completed, the SSC will have about 20 times the power of the Tevatron (40 trillion electron volts). The proposed Texas site for the SSC was selected by DOE in January 1989.

Argonne National Laboratory is developing a magnetohydrodynamic (MHD) propulsion system for military and commercial use. The MHD propulsion system has no moving parts, but uses magnetic fields and electricity to pump water through a tube. Researchers at Argonne will use the world's largest helium-cooled superconducting dipole magnet to study the propulsion system. Development of this technology could lead to a new generation of water transportation vessels that would travel more quickly, quietly, and efficiently than present ships.

Testing of the six liquid helium-cooled electromagnets supplied for the Large Coil Task was completed at Oak Ridge National Laboratory last year. These six magnets each incorporated slightly different designs, which were tested to determine the best configuration for the confinement of fusion systems in the production of "clean" nuclear energy. Although these magnets are the largest ever tested (8 tesla, or 160,000 times as strong as the magnetic field of the Earth), they are only one-third to one-half the size of those needed for proposed fusion reactors. Successful operation of these magnets gives researchers more confidence in the use of superconducting magnets for fusion containment.

Liquid helium use in magnetic resonance imaging (MRI) continues to increase as the medical profession accepts and develops new uses for this equipment. MRI equipment is providing accurate diagnosis of medical problems where exploratory surgery was required previously. Another medical application being developed uses MRI to determine by blood analysis if a patient has any form of cancer. Most researchers seem to think it will be at least 5 to 10 years before the new high-temperature (about −300 °F) superconducting materials affect liquid helium demand.

Lifting gas applications are increasing. The U.S. Navy and U.S. Air Force are investigating the use of airships to provide early warning systems to detect low-flying cruise missiles. The Drug Enforcement Administration has installed six tethered radar blimps along the southern border of the United States to detect drug smugglers. In addition, NASA is now using helium-filled balloons to sample the atmosphere in Antarctica to determine what is depleting the ozone layer that protects the Earth from harmful ultraviolet radiation. Similar work is also underway in the Arctic. A stealth blimp is being tested by the Army's Intelligence and Electronic Warfare Center in New Jersey. In the commercial market, many companies besides Goodyear are now using "blimps" for advertising.

Helium is being used to develop several Strategic Defense Initiative (SDI) applications such as the antisatellite (ASAT) rocket, chemical laser, and rail gun. The ASAT rocket uses liquid helium-cooled infrared sensors for target location and guidance. Gaseous helium is used in the lasing gas mixture of the chemical laser, and liquid helium is used to cool the tracking telescope. This telescope is used to locate the target and aim the laser beam. High-pressure gaseous helium provides the initial push that inserts the projectile into the bore of the rail gun at a velocity of about 1,100 miles per hour. Electromagnetic energy applied along the bore accelerates the projectile to a final velocity of about 9,000 miles per hour.

Superconducting magnetic energy storage (SMES) is also being investigated to provide power for Defense laser systems. SMES allows the accumulation and storage of electrical energy over the long term (hours) and discharges it in minutes.

Other evolving technologies that require the unique properties of helium are (1) metastable helium for energy storage, which involves raising helium electrons to an excited energy state and then stabilizing the atom there; (2) fiber-optic production, where an ultrapure atmosphere is required; (3) helium-filled plastic pillows, where low density is required to simulate a precursor wave from a nuclear blast; (4) helium ion tumor treatment, where large inert particles are required; (5) liquid helium-cooled superconducting microswitches, called Josephson junctions, which are much faster than conventional semiconductors and use less power; (6) "Aneutronic" nuclear fusion where nuclear energy is produced by fusion of deuterium and helium-3, which produces few or no neutrons; and (7) new helium-hydrogen breathing mixtures that enable deep-sea divers to reach depths below 1,700 feet.

## ANNUAL REVIEW

### Legislation and Government Programs

The Government's program for storage of private crude helium in the Government's helium storage facilities at the Cliffside Field near Amarillo, TX, was vital in supplying helium for the private helium market. Excess helium production of private industry obtained from natural gas supplying fuel markets in the winter is stored by the Government under contract. This privately owned crude helium is returned to the owners for purification as needed to provide for private industry demand. Privatization of all the Government's helium program, except the conservation storage operation, is under consideration.

## Production

In 1990, 12 privately owned domestic helium plants were operated by 10 companies. Eight of the privately owned plants and the U.S. Bureau of Mines plant extracted helium from natural gas. Both private and Bureau plants use cryogenic extraction processes. The volume of helium recovered from natural gas decreased 3%, while sales increased about 6% in 1990. A shortage of private helium production was prevented by purifying crude helium that had been stored in the Government's Cliffside Field. All natural gas processed for helium recovery came from gasfields in Colorado, Kansas, New Mexico, Oklahoma, Texas, and Wyoming. Seven private plants and the Bureau's plant purified helium this year. Pressure-swing adsorption is used for helium purification at five of the private helium plants and at the Bureau's plant. Cryogenic purification is used by the other producers and provides backup at the Bureau's plant. The Bureau and six private plants that produce Grade-A helium also liquefy helium. The plant operators and locations are Air Products and Chemicals Inc., Hansford County, TX; Navajo Refined Helium Co., Shiprock, NM; Kansas Refined Helium Co., Otis, KS; Exxon Co., U.S.A., Shute Creek, WY; and Union Carbide Corp., Linde Div., Bushton and Ulysses, KS. Nitrotec's new helium plant near Burlington, CO, produces Grade-A helium but does not liquefy helium. Linde's helium plant at Elkhart, KS, was shut down in 1988.

## Consumption and Uses

The major domestic end uses of helium were cryogenics, welding, and pressurizing and purging. Minor uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. The Pacific and Gulf Coast States were the principal areas of helium consumption.

Bureau sales to Federal agencies and their contractors totaled 403 MMcf in 1990, an increase of about 15% when compared with last year's sales. This increase was due largely to NASA's resumption of space shuttle flights, which include associated projects that use large volumes of helium. Sales to DOE continue to decline.

The Federal agencies purchase their major helium requirements from the

TABLE 1

### OWNERSHIP AND LOCATION OF HELIUM EXTRACTION PLANTS IN THE UNITED STATES IN 1990

| Category and owner or operator | Location | Product purity |
|---|---|---|
| Government-owned: | | |
| Bureau of Mines | Masterson, TX | Crude and Grade-A helium.[1] |
| Private industry: | | |
| Air Products and Chemicals Inc. | Hansford County, TX | Grade-A helium.[1] |
| KN Energy Inc. | Scott City, KS | Crude helium.[2] |
| Nitrotec | Burlington, CO | Grade-A helium. |
| Oxy NGL Inc. | Ulysses, KS | Crude helium. |
| Exxon Co. U.S.A. | Shute Creek, WY | Grade-A helium.[1] |
| Kansas Refined Helium Co. | Otis, KS | Do. |
| Navajo Refined Helium Co. | Shiprock, NM | Do. |
| Enron Helium Co. | Bushton, KS | Crude helium. |
| Phillips Petroleum Co. | Dumas, TX | Do. |
| Do. | Hansford County, TX | Do. |
| Union Carbide Corp., Linde Div. | Bushton, KS | Grade-A helium.[1] |
| Do. | Elkhart, KS | Deactivated. |
| Do. | Ulysses, KS | Grade-A helium.[1] |

[1] Including liquefaction.

[2] Output is piped to Ulysses, KS, for purification.

TABLE 2

### HELIUM RECOVERY IN THE UNITED STATES[1]

(Thousand cubic feet)

| | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|
| Crude helium: | | | | | |
| Bureau of Mines total storage | −379,827 | −289,085 | −359,409 | −377,508 | −462,812 |
| Private industry: | | | | | |
| Stored by Bureau of Mines | 431,917 | 730,360 | 630,748 | 547,158 | 507,057 |
| Withdrawn | −980,209 | −697,266 | −551,997 | −653,263 | −766,684 |
| Total private industry storage | −548,292 | 33,094 | 78,751 | −106,105 | −259,627 |
| Total crude helium | −928,119 | −255,991 | −280,658 | −483,613 | −722,439 |
| Stored private crude helium withdrawn from storage and purified by the Bureau of Mines for redelivery to industry | −18,658 | −6,765 | −11,920 | −5,482 | −6,401 |
| Grade-A helium: | | | | | |
| Bureau of Mines sold | 333,447 | 266,594 | 316,954 | 350,154 | 402,706 |
| Private industry sold | 1,607,963 | 1,963,750 | 2,256,997 | 2,529,226 | 2,655,848 |
| Total sold | 1,941,410 | 2,230,344 | 2,573,951 | 2,879,380 | 3,058,554 |
| Total stored | −946,777 | −262,756 | −292,578 | −489,095 | −728,840 |
| Grand total recovery | 994,633 | 1,967,588 | 2,281,373 | 2,390,285 | 2,329,714 |

[1] Negative numbers (−) denote net withdrawal from the Government's underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.

FIGURE 1

**HELIUM RECOVERY IN THE UNITED STATES**

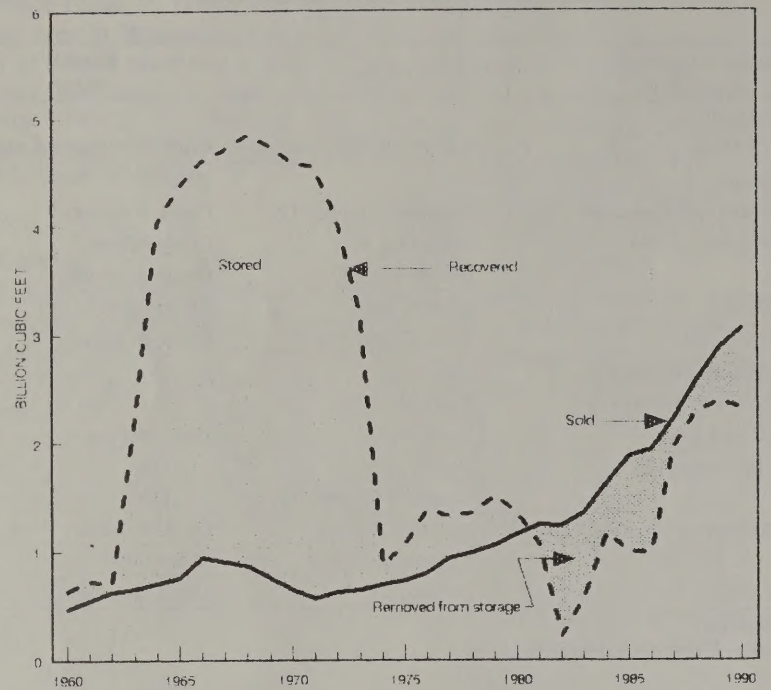



FIGURE 2

**MAJOR U.S. HELIUM-BEARING NATURAL GASFIELDS**

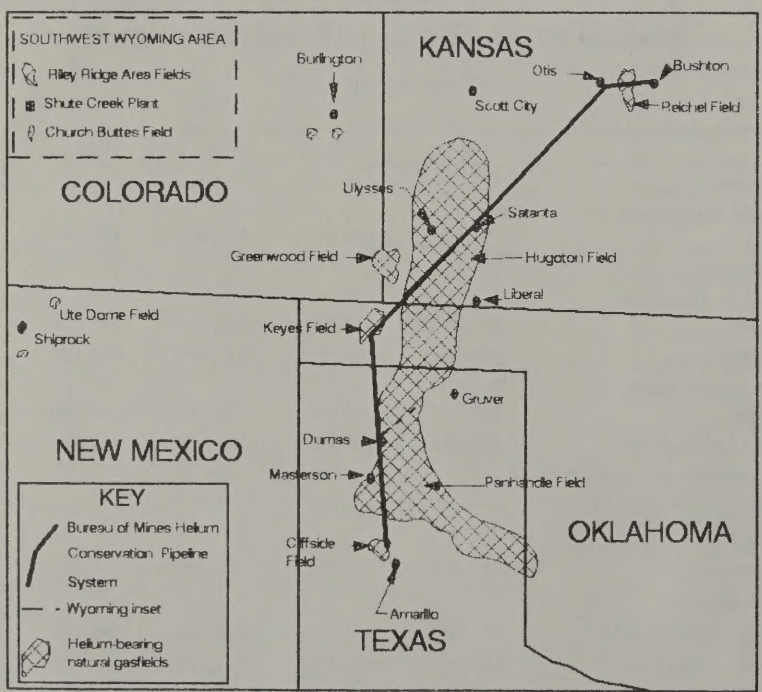



TABLE 3

**TOTAL SALES OF GRADE-A HELIUM PRODUCED IN THE UNITED STATES**

(Million cubic feet)

| Year | Volume | | |
|---|---|---|---|
| | Domestic sales | Exports[1] | Total sales |
| 1986 | 1,509 | 432 | 1,941 |
| 1987 | 1,736 | 494 | 2,230 |
| 1988 | 1,911 | 663 | 2,574 |
| 1989 | 2,083 | 796 | 2,879 |
| 1990 | 2,167 | 892 | 3,059 |

[1] Source: Bureau of the Census.

U.S. Bureau of Mines. Direct helium purchases by the Department of Defense, NASA, DOE, and the National Weather Service constituted most of the Bureau's Grade-A helium sales. All remaining helium sales to Federal agencies were made through Bureau contract distributors, who purchased equivalent volumes of Bureau helium under contracts described in the Code of Federal Regulations (30 CFR 602). Some of the contract distributors also have General Services Administration helium supply contracts. These contracts make relatively small volumes of helium readily available to Federal installations at lower freight charges by using the contractors' existing distribution systems.

## Stocks

The volume of helium stored for future use in the U.S. Bureau of Mines helium conservation storage system, which includes the conservation pipeline network and the Cliffside Field near Amarillo, TX, totaled 34.4 Bcf at yearend. The conservation storage system contains crude helium purchased by the Bureau under contract, Bureau helium extracted in excess of sales, and privately owned helium stored under contract. During 1990, 507 MMcf of private helium was delivered to the Bureau's helium conservation storage system and 773 MMcf was withdrawn for a net decrease of 266 MMcf of private helium in storage.

## Transportation

All Grade-A gaseous helium sold by the Bureau was shipped in cylinders, modules (large gas cylinders), special railway tankcars, or highway tube semi-

TABLE 4

## SUMMARY OF BUREAU OF MINES HELIUM CONSERVATION STORAGE SYSTEM OPERATIONS[1]

(Thousand cubic feet)

| | 1988 | 1989 | 1990 |
|---|---|---|---|
| Helium in conservation storage system at beginning of period: | | | |
| Stored under Bureau of Mines conservation program | 34,116,084 | 33,756,675 | 33,379,167 |
| Stored for private producers under contract | 1,799,774 | 1,866,605 | 1,755,018 |
| Total | 35,915,858 | 35,623,280 | 35,134,185 |
| Input to system: | | | |
| Net deliveries from Bureau of Mines plants[2] | −359,409 | −377,508 | −462,812 |
| Stored for private producers under contract | 630,748 | 547,158 | 507,057 |
| Total | 271,339 | 169,650 | 44,245 |
| Redelivery of helium stored for private producers under contract[2] | −563,917 | −658,745 | −773,085 |
| Net addition to system[2] | −292,578 | −489,095 | −728,840 |
| Helium in conservation storage system at end of period: | | | |
| Stored under Bureau of Mines conservation program | 33,756,675 | 33,379,167 | 32,916,355 |
| Stored for private producers under contract | 1,866,605 | 1,755,018 | 1,488,990 |
| Total | 35,623,280 | 35,134,185 | 34,405,345 |

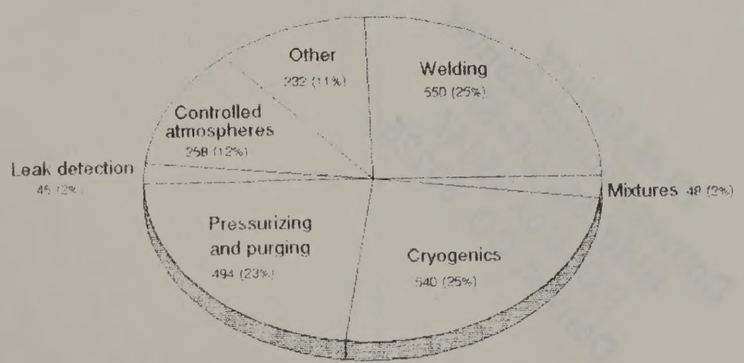
[1] Crude helium is injected into or withdrawn (−) from the Government's underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.

[2] Negative numbers denote net withdrawal from storage.

FIGURE 3

## ESTIMATED HELIUM CONSUMPTION, BY END USE, IN THE UNITED STATES IN 1990

(Million cubic feet)




Estimated total helium used
(2,167 million cubic feet)

trailers. Small gas cylinders are filled at the Amarillo plant, and railway tankcars are filled at the Exell plant. Other shipping containers for gaseous helium may be filled at either plant. Bureau liquid helium was shipped in dewars and semitrailers from the Exell plant. Private producers and/or distributors shipped helium primarily as a liquid in semitrailers. These semitrailers delivered the liquid helium to distribution centers where some of it was gasified and compressed into trailers and small cylinders for delivery to the end user. The remaining liquid helium was sold as bulk liquid or repackaged in dewars of various sizes for delivery.

### Prices

The U.S. Bureau of Mines price, f.o.b. plant, for Grade-A helium has been maintained at $37.50 per Mcf since October 1, 1982, when it was raised from the $35.00 per Mcf price established in 1961. The price for Grade-A helium from private producers is also about $37.50 per Mcf. The Bureau trailer-load liquid helium price was $45 per Mcf during all of 1990, with additional charges for container services and rent. The typical private industry price for liquid helium was also $45 per Mcf gaseous equivalent plus surcharges. The Bureau has submitted a report to Congress on options for the routine adjustment of helium prices.

### Foreign Trade

Exports of Grade-A helium, all by private industry, increased by 12% in 1990 to 892 MMcf (table 3). About 52% of the exported helium was shipped to Europe. Belgium-Luxembourg, France, and the United Kingdom, collectively, received about 88% of the European helium imports. About 33% of the U.S. helium exports went to Asia, with Japan taking about 87% of this helium. Other exports were as follows: more than 7% to North America; about 2% each to Australia-New Zealand, Middle East, and South America; and less than 1% each to Africa, the Caribbean, and Central America. The shipments of large volumes of helium to Western Europe were attributed to helium use in cryogenic research and superconducting equipment. Significant volumes were also being used in breathing mixtures for diving, welding, and as a lifting gas. Although no helium was imported in

1990, import tariffs on helium remained at the 3.7% rate established on January 1, 1987. No further decreases in import tariffs are scheduled.

### World Review

World production of helium, excluding the United States, was estimated to be 300 MMcf, most of which was extracted in Poland and the U.S.S.R. The remainder was produced in small plants in China and India.

## OUTLOOK

Until recently, all superconductors required liquid helium (−452 °F) to reach superconducting temperatures. Current research on superconductors has resulted in the discovery of superconducting materials that operate above liquid nitrogen temperatures (−320 °F). These new superconductors have physical limitations, such as brittleness and poor current-carrying capacities, which have precluded their use in most superconducting applications. If these problems are solved, the new materials could replace liquid helium-cooled superconductors.

Since 1986, the market for U.S. produced helium has grown at an average annual rate of 12%. Private industry's market has been growing at 13.4% per year, while the Federal market has grown at 4.9%. The Federal market has reached its highest volume in more than 20 years. At the present time, private industry is supplying about 87% of the demand for U.S. produced helium, while the Bureau is supplying the remaining 13%. Private industry supplies all of the U.S. helium exports. The foreign market made up about 26% of U.S. helium sales in 1990 and has grown at an average rate of approximately 20% per year since 1986.

At the present time, the outlook for helium looks good, with growth continuing in new technologies that use helium. The adverse impact of high-temperature superconductors, if any, is not expected for several years.

TABLE 5

**WORLD GRADE-A HELIUM PRODUCTION CAPACITY, DECEMBER 31, 1990**

(Million cubic feet)

| | Capacity |
|---|---|
| United States | [1]3,400 |
| Rest of world[e] | 300 |
| Total[e] | 3,700 |

[e] Estimated.
[1] Includes capacity of plants on standby as well as operating plants.

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[1] All helium volumes herein reported are at 14.7 pounds per square inch absolute and 70° F.

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☆ U.S. Government Printing Office : 1991 -281-983/40084